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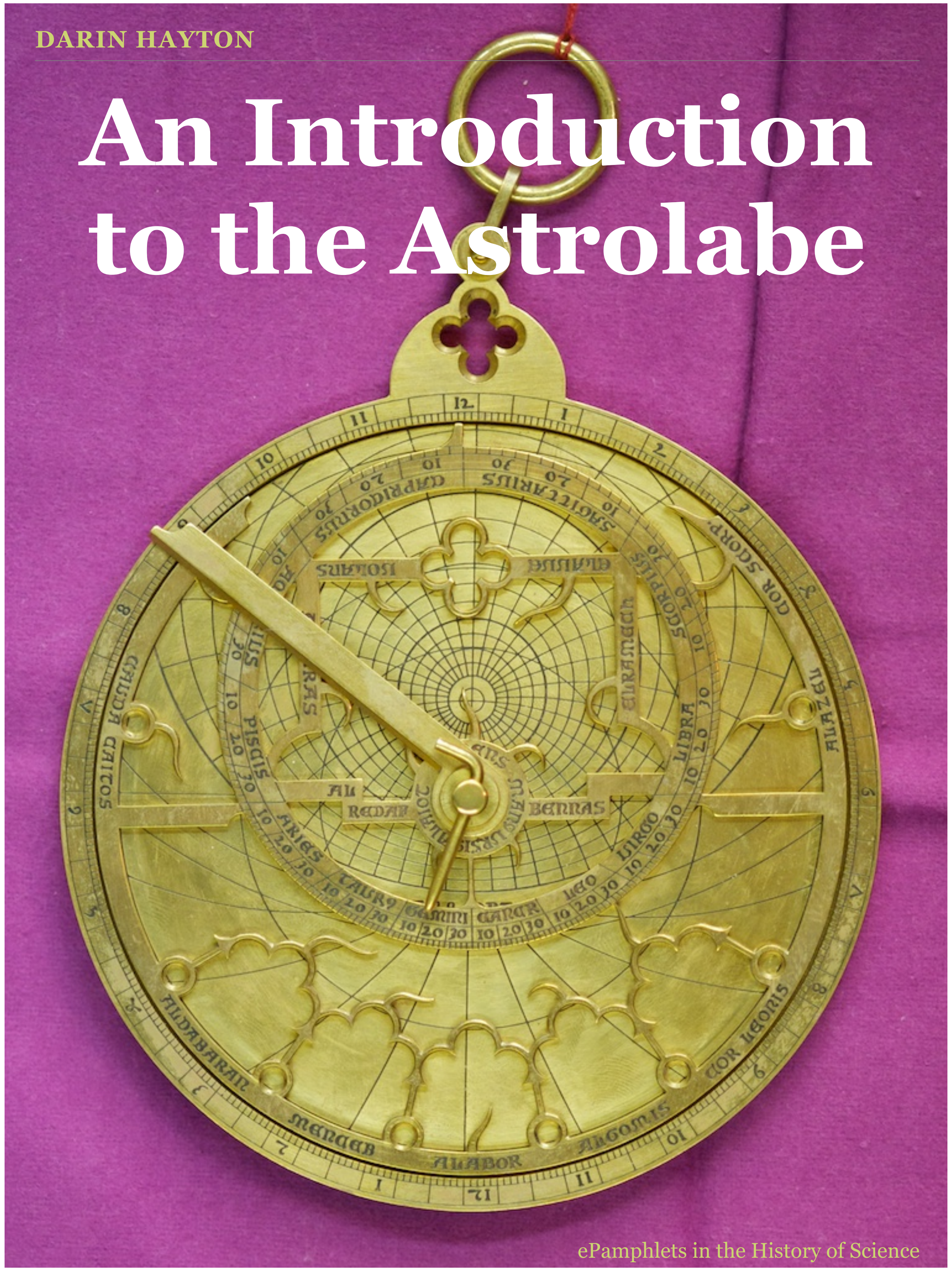
An Introduction to the Astrolabe



ePamphlets in the History of Science

An Introduction to the Astrolabe

Nota bene: When reading this on an iPad, most of the images will only display in “landscape” orientation. For that reason, portrait orientation was disabled.

The astrolabe pictured on the cover and used in illustrations throughout this pamphlet was made by the craftsman Martin Brunhold. His other instruments can be seen on his webpage: <http://www.astrolabe.ch/>

Preface

“An Introduction to the Astrolabe” offers a short history of this fascinating instrument and a brief introduction to the parts of an astrolabe.

The history of the astrolabe begins in Alexandria with its rich tradition of supporting scientific activities. From there, we move to the Byzantine Empire and then to the Islamic world, where the astrolabe flourished from India at the eastern end to Muslim Spain in the west. When Latin scholars traveled to Spain to acquire the training and knowledge common in the Islamic world they returned with texts on astrolabes as well as astrolabes themselves. Soon, scholars in medieval Europe were composing their own texts and making their own instruments. In western Europe the production of texts and instruments reached their peak in the sixteenth century and then rapidly declined, as the astrolabe was replaced by other instruments. Craftsmen in the Islamic world continued producing astrolabes for another century or two.

The history of the astrolabe has two main currents, a textual history and a history of instruments. It is impossible to disentangle the two, or to understand either history without the other. Our earliest evidence for the astrolabe is comes from textual sources. Similarly, the history of the astrolabe in the Byzantine Empire must be reconstructed from textual sources. We are more fortunate when studying the Islamic world or Western Europe. The hundreds of instruments that survive from these contexts help fill in the picture of what astrolabes were, how they functioned, who made them, and who owned them.

“An Introduction to the Astrolabe” is the first in what is hoped will be a series of “ePamphlets in the History of Science.” These ePamphlets will appear occasionally and will provide a sketch of some topic or episode in the history of science, technology, or medicine. They are intended for a general audience—anybody with an interest in the history of science. They will often be merely introductions to some topic. Some ePamphlets will focus on an interesting episode that illustrates a broader topic in the history of science.

In addition to the general reader, it is hoped that these pamphlets will be of some use to educators, both in secondary education and the undergraduate level. These ePamphlets in the History of Science are not intended to be definitive or schol-

arly. Rather, think of them as smart, popular texts aimed at disseminating the history of science to a broader audience.

Chapter 1

A History

Legend claims that one day when Ptolemy was riding a camel he dropped his celestial globe in the sand. The camel stepped on the globe, flattening it. Seeing the disc, Ptolemy realized that he could project the three-dimensional sky on a two-dimensional disc. While quaint and amusing, the story is surely false.

SECTION 1

The Early History

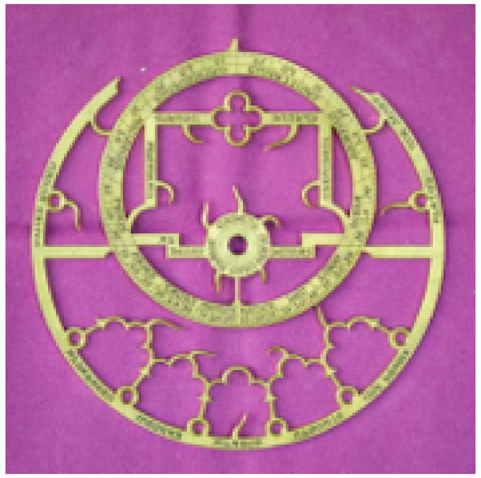
KEY MOMENTS

- Hipparchus first described the stereographic project used for an astrolabe around 150 BCE.
- Around 150 CE Ptolemy describes an instrument very similar to an astrolabe.
- In the 4th century Theon of Alexandria writes a treatise on the astrolabe.
- John Philoponus' 6th-century work on the astrolabe is the oldest surviving text.
- By the 9th century the Islamic world was producing both the most beautiful astrolabes and most sophisticated texts.
- Although there are numerous Byzantine texts, only one complete astrolabe survives, from the 11th century.

The astrolabe is an ancient astronomical instrument that was used both to make observations and to carry out calculations. It was the most widely used scientific instrument in the middle ages and into the early modern period. The history of the astrolabe begins in the Hellenistic World of Alexandria. From there it spreads north into the Byzantine world and east through the Islamic world and into India. Later, knowledge of the astrolabe traveled west across North Africa and into Muslim Spain. In the Latin middle ages, scholars from northern Europe traveled to Spain and returned with astrolabes and texts describing them. The history of the astrolabe is a history of technical, scientific knowledge embodied in instruments, texts, and practices. *An Introduction to the Astrolabe* introduces the reader to that history, tracing it from antiquity to modern day collections.

ANTIQUITY

The origins of the astrolabe remain uncertain. The earliest surviving instruments date from medieval Islam. However, Greek and Syriac texts testify to a long theoretical and practical development that extends back to the second century BCE. The underlying mathematical principle of stereographic projection was described by Hippar-



The rete, or spider, is the network of stars on an astrolabe.

chus of Nicaea (fl. 150 BCE). Less than two centuries later, Vitruvius (died post 27 CE) described a type of clock that depended on a similar stereographic projection. His suggestion that Eudoxus of Cnidos (ca. 408-355 BCE) or Apollonius of Perga (ca. 265-170 BCE) invented the rete or spider—the network of stars—almost certainly refers to the sundials he was discussing in the passage. Claudius Ptolemy (fl. 150 CE), the most famous astronomer from antiquity, wrote an extensive theoretical treatment of stereographic projection in his *Planisphaerium*, which included a short discussion of a horoscopic instrument. Although he described an instrument that resembles an astrolabe, including both a rete and the stereographic projection of a coordinate system, Ptolemy's instrument does not seem to have included the apparatus needed to make direct observations and thus to measure the altitude of the sun or stars.

Late Antiquity & Byzantium

As early as the fourth century authors began composing manuals on the astrolabe. Theon of Alexandria's (fl. 375 CE) work "On the Little Astrolabe" is the earliest text to treat the construction and use and of the astrolabe. It became a model both in form and content for later literature on the astrolabe. After Theon, treatises on the astrolabes became increasingly common. Synesius of Cyrene (ca. 370-415 CE) wrote a short work on the astrolabe and mentions a silver planisphere that he sent to Paeonius in Constantinople. The Byzantine scholar Ammonius (died post 517 CE) reportedly wrote a treatise on the construction and use of the astrolabe. More importantly, Ammonius incorporated the astrolabe into his teaching, thereby introducing a number of people to the instrument. The oldest surviving treatise on the astrolabe comes from his most famous pupil, the mathematician and philosopher John Philoponus (ca. 490-574 CE). In 530 he wrote wrote a work entitled "On the use and construction of the astrolabe and the lines engraved on it."

Philoponus' text offers a practical description of the astrolabe and surveys its most common uses. In the middle of the seventh century, Severus Sebokht of Nisibis, Bishop of Kennesrin in Syria, wrote a description of the astrolabe in Syriac. Sebokht's exposition conforms to the patterns established by Theon and adopted by subsequent authors. Like his predecessors, he eschewed theoretical discussions, concentrating instead on practical description and application. He greatly expanded the standard list of uses. Knowledge and production of the astrolabe spread from the Byzantine and Syro-Egyptian context east through the Syrian city of Ḥarrān and into Persia.

From Byzantium to Islam

Ḥarrān had been an important center of pre-Islamic translation activity. With the rise of the ʻAbbāsid caliphs came a new interest in Greek science and technology, both of which played a key role in efforts to legitimate their rule. Al-Manṣūr (712-775 CE, caliph from 754), the second ʻAbbāsid caliph, supported the translation of Greek science into Arabic and promoted various sciences, especially astronomy and astrology. Increasingly he relied on court astrologers: on their advice he

selected 30 July 762 CE as the day to lay the foundations of Baghdad; he consulted with them when his relatives revolted; and they accompanied him on his pilgrimages to Mecca. In this context the astrolabe was a useful tool. Al-Manṣūr's great grandson, al-Ma'mūn (787-833 CE, caliph from 813) consolidated and extended this policy. In addition to their political uses, astrolabes had immediate religious applications. The close connection between astronomy and Islam provided an obvious incentive for developing the astrolabe. Finding the times of the five daily prayers as well as the direction of Mecca are both complicated astronomical and geodetic operations. Makers quickly perfected techniques that made it possible to determine through direct observation both the time of prayer and the direction of Mecca.

Over the next few centuries Arab, Persian, and Jewish scholars produced numerous systematic treatises on the astrolabe. The earliest of these was written by Messahalla, a Jew from Basra, whose work dates from before 815 CE. The original Arabic treatise has been lost, but numerous Latin translations of it survive. The oldest surviving Arabic treatises date from the early ninth century. Al-Kwārizmī (fl. 825 CE) wrote two short texts, one on the construction and one on the use of the astrolabe. Other early texts by ʻAlī ibn ʻĪsā (fl. 830 CE) and Aḥmad ibn Muḥammad ibn Katir al-Fargānī (fl. 857 CE) also survive. Along with his treatise on the astrolabe, ʻAlī ibn ʻĪsā made various astronomical observations in Baghdad and Damascus under the patronage of al-Maʻmūn. In the early eleventh century al-Bīrūnī (973–1048 CE), a Persian scholar, wrote his Book of Instruction in the Elements of the Art of Astrology, which included detailed descriptions of the construction, parts and uses of the astrolabe. During this same period, making astrolabes developed into a well respected profession. Arab craftsmen developed their skills and tacit knowledge, creating family workshops that continued for a number of generations. The oldest surviving astrolabes date from this period of intellectual efflorescence supported by the early Islamic caliphs.

Into India and China

Traveling Persians scholars like al-Bīrūnī probably introduced the astrolabe to the Hindus quite early, and later scholars brought astrolabes to the court in Delhi. During the fourteenth century, the Sultan Fīrūz Shāh Tughluq (1300-1388 CE, reigned from 1351) sponsored the manufacture of astrolabes. The first Sanskrit treatise on the astrolabe, entitled Yantaraja ("King of astronomical instruments"), was written in 1370 by a Jaina monk, Mahendra Sūri (1340-1410 CE). Mughal India adopted the instrument with great enthusiasm in the mid-sixteenth century. The new rulers relied heavily on astrology to regulate their affairs and considered the astrolabe a valuable astrological and political tool. Contemporary chronicles emphasize Emperor Humāyūn's (1508-1556 CE, reigned from 1530-40 and 1555-6) interest in astrolabes. Under Humāyūn's patronage, Lahore, in present-day Pakistan, became the center of production of Indo-Persian astrolabes. One family came to dominate the manufacture of astrolabes in Lahore, producing more than 100 astrolabes over the next century. The most prolific and famous member of this family was

Ḍiyā’ al-Dīn Muḥammad (fl. 1645-1680 CE), who produced more than 30 astrolabes between 1645 and 1680 CE.

Much later, Jaipur, in northern India, developed into an important city for the production of Indian astrolabes. Jaipur’s rise to prominence corresponds to the Maharajah Sawai Jai Singh II’s (1686-1743 CE) efforts to build the great observatories in the city. Jai Singh had also written a book on the construction of the astrolabe and founded a center for their manufacture. Indian instruments from Jaipur are often notable for their size and by the fact that they have a single plate engraved for the 27°, the latitude of Jaipur.

By the thirteenth century knowledge of the astrolabe had reached China. In 1267 Jamal al-Din brought Kublai Khan models of various astronomical instruments that were in use at the observatory in Maraghah. Marco Polo claimed to have seen astrolabes in Beijing and within a century, *The Travels of Sir John Mandeville* describe astrolabes at Kublai Khan’s court. Despite these reports, which are themselves problematic, the astrolabe does not seem to have been as popular in Chinese culture as it was elsewhere.

Byzantium and North Africa

Numerous treatises testify to the importance of the astrolabe in the Byzantine Empire. Greek scholars profited from having uninterrupted access to the earliest treatises on astrolabes and composed numerous manuals on the astrolabe. An almost continuous series of texts extend from Philoponus’ treatise in the early sixth century to Nikephoros Gregoras’s (ca. 1292-1360 CE) treatise in the fourteenth. These Byzantine manuals, especially Gregoras’s, played an important role in later European texts of the sixteenth and seventeenth centuries. Surprisingly, only one complete Byzantine astrolabe, dated 1062, has been identified.

By the tenth century, astrolabe production spread west across North Africa and into Muslim Spain. In direct contrast to the history of the astrolabe in Byzantium, its history in North Africa is characterized by a wealth of instruments and dearth of texts. North African, or Maghribi, astrolabes share conservative stylistic features that set them apart from the eastern Islamic instruments. They also reveal a closer connection to Christian Europe, most notably in the presence of the Christian calendar frequently found on the back of these instruments. Although astrolabes were produced and used across North Africa, the tradition was strongest in Morocco, where they were manufactured and used for more than 500 years. By the early fourteenth century, sophisticated universal astrolabes were being produced in the Moroccan city of Taza. Along with Taza, cities like Marrakesh, Fez and Meknes became associated with both the manufacture and use of astrolabes. Muḥammad ibn Aḥmad al-Baṭṭuṭī, one of the most prolific makers from North Africa, was still producing astrolabes in Morocco as late as the eighteenth century.

Section 2

Medieval History

Key Moments

- Gerbert of Aurillac, later Pope Sylvester II, introduced the astrolabe to students at the monastery in Reichenau.
- Hermann Contractus of Reichenau's *De utilitatibus astrolabii* was one of the first texts on the astrolabe composed in Latin.
- Between the 11th and 13th centuries, most astrolabes in Europe were imported from Muslim Spain.
- In the 14th century, Geoffrey Chaucer wrote a text on the astrolabe for his son.
- The Parisian Jean Fusoris became the most famous astrolabe maker in Europe in the latter 14th century.

The astrolabe was probably introduced into Muslim Spain through Cordoba, at that time the capital of the Ummayad Emirs. Scholars throughout Spain were quick to adopt the astrolabe. By the late tenth century astrolabes and manuals on their use were being produced throughout the Muslim Spain. These instruments show many similarities with those produced in North Africa. At the same time, Spanish makers developed a style that distinguished their astrolabes from the Maghribi instruments. Muslim Spain also provided an important context for the diffusion of astrolabes into Christian Europe. Arabic texts on the astrolabe were translated into Latin, making them accessible to European scholars who came to Spain looking for Greek and Arabic knowledge.

Gerbert of Aurillac (ca. 945-1003 CE), who became Pope Sylvester II in 999 CE, was one of the first European scholars to establish intellectual contact between Latin Christendom and Islam. He traveled to Catalonia to complete his education and acquire books on various mathematical subjects, including the astrolabe. When he returned from Spain he probably brought with him copies of Llobet of Barcelona's (fl. late tenth century CE) Latin translations of Arabic manuals on astronomy, astrology and the astrolabe. Gerbert remained in close contact with Spanish scholars, requesting additional books and translations. He introduced the astrolabe to his students at Rheims. Knowledge of the astrolabe spread quickly throughout Europe. Within fifty years, a copy of Llobet's text on the astrolabe was in the monastery at Reichenau in Carinthia,

where Hermann Contractus of Reichenau (1013-1054 CE) relied on it when writing his own his *De utilitatibus astrolabii*.

Along with texts on the astrolabe, northern European scholars acquired actual instruments. By 1025 Rudolf of Liège could boast of owning an astrolabe, and Walcher of Lorraine (died 1135 CE), the prior of the Abbey of Malvern, used his own astrolabe to determine the time of a lunar eclipse on 18 October 1092. Between the 11th and 13th centuries, the majority of astrolabes in northern Europe were imported from Muslim Spain. Like texts, these instruments were often translated into Latin so that their new owners could understand them. Often the new owner engraved the Latin names above the Arabic words for the months or engraved the standard symbols for the zodiacal signs. For centuries Spanish astrolabes were recognized as valuable possessions and useful tools — Martin Bylica (1433-ca.1493 CE) was still using an astrolabe from Cordoba in the late fifteenth century.

Soon, manuals on the construction and use of the astrolabe became common in universities throughout Europe. Indeed, in the 1390s Geoffrey Chaucer thought it necessary to send his son off to study at Oxford with both an astrolabe and a manual on its use. For this occasion, Chaucer wrote the first English text on using the astrolabe, his *A Treatise on the Astrolabe*. Chaucer might have composed this work with a particular astrolabe at hand. In any case, the text was clearly meant to be used alongside an actual instrument.

Chaucer was able to give his son an astrolabe because the instruments had become increasingly common in Europe as workshops began to form around individual craftsmen. The most famous of the early astrolabists was the Parisian Jean Fusoris (ca. 1365-1436), whose instruments were highly sought and widely copied. Fusoris was both a scholar and a craftsman as well as successful entrepreneur and convicted spy. His instruments are cleanly engraved and largely unadorned, but nonetheless elegant. He introduced a range of innovations, such as equal-hour lines on the limb and rule on the front of the astrolabe, which he had discussed in his treatise on astrolabes. Perhaps more significant for the the history of astrolabes, he was the first of the scholar-craftsmen who would come to dominate the production of instruments during the Renaissance. He set up a commercial workshop in Paris that produced astrolabes, along with clocks and other astronomical instruments. No longer were individual scholars required to make their own instruments. Instead, Fusoris and the makers who followed him combined theoretical and practical knowledge with commercial interests and established workshops that made instruments for an increasingly broad market.

SECTION 3

Early Modern History

KEY MOMENTS

- By the 14th century princes increasingly collected astrolabes.
- Georg Hartmann established a workshop in Nuremberg and quickly became one of the most important makers in the early 16th century.
- By the end of the 16th century, the center of production had moved to Louvain and the workshops of Gemma Frisius and later Gualterus Arsenius.
- In the 17th century, Robert Dudley gave a large astrolabe to Queen Elizabeth I.
- Holy Roman Emperor Rudolf II owned at least eight astrolabes.

Although the early trade in astrolabes centered on universities, by the fourteenth century astrolabes were increasingly collected and used by princes, kings and emperors throughout Europe. As early as the twelfth century, Adelard of Bath (fl. 1116-1142 CE) dedicated a treatise on the astrolabe to the future King Henry II of England while tutoring him in Bristol during the 1140s. Charles V of France (1337-1380 CE) owned twelve astrolabes. Martin Bylica accompanied the Hungarian king Matthias Corvinus on military and diplomatic journeys and regularly used his astrolabe to determine propitious times to engage in battle or sign treaties. Andreas Stiborius (1465-1515 CE) created various paper astrolabes for the Holy Roman Emperor Maximilian I (1453-1519 CE), who in 1507 used one of these paper astrolabes to determine the best time to sign a peace treaty with the Hungarian King Ladislaus.

Queen Elizabeth I of England (1533-1603 CE) had two astrolabes, one of which is dated 1559, the year of her coronation. This astrolabe may have been given to the Queen by Robert Dudley, future Earl of Leicester in response to being installed as Knight of the Garter.

The Holy Roman Emperor Rudolf II (1552-1612 CE) had no fewer than eight astrolabes in his collection of scientific instruments and was renowned for supporting instrument makers. One of the more prolific makers to enjoy the emperor's generous patronage was Erasmus Habermel, who created beautiful astrolabes and other instruments for the emperor's family as well as other princes and dukes throughout Europe.

In Europe, interest in the astrolabe peaked in the sixteenth century. Introductory texts outlining the astrolabe's uses were produced in small, cheap formats, making them available to a broad audience. These texts offered the reader a pragmatic set of canons for the most common uses, such as telling time, determining the rising sign or drawing a horoscopic chart. At the same time, large, richly illustrated and expensive works appealed to a more select public. These texts detailed various construction techniques, offered the most current data needed to arrange the stars and presented the historical development for most uses. The most famous of these ornate volumes were produced by Johannes Stöffler (1452-1531 CE), Peter Apian (1495-1552 CE), and Andreas Schöner (1528-1590 CE), which quickly became the standard by which others were judged. Some of these texts were enlarged and reprinted while others were translated into a local vernacular and reprinted in a smaller, more affordable formats. Texts written in the vernacular were quickly translated into Latin so that they could be sold to a broader audience. This publishing activity addressed only a portion of the rising interest in astrolabes.

The sixteenth century also witnessed a dramatic increase in the number of European instrument makers. The natural resources and tradition of metal working that had made the Nuremberg-Augsburg region of southern Germany the center of instrument production in the late fifteenth century continued into the sixteenth. Makers in both Augsburg and Nuremberg benefited from the commercial interests of the Fugger family who had a monopoly on the Central European mining industry. In the first half of the sixteenth century, brass and copper were readily available in both cities but were more difficult to obtain and more expensive in other parts of Europe. It is not surprising, then, that the southern German makers had a near monopoly on the production of astrolabes and other instruments. The most famous of them was Georg Hartmann (1489-1564 CE). His "Collectanea mathematica," written in 1527-1528, focuses on the construction of astrolabes and related instruments and testifies to Hartmann's early interest in astrolabes. By the 1520s he had settled in Nuremberg and set up a workshop in which the various parts of astrolabes were constructed by individual craftsmen and then assembled. This enabled him to produce a large number of instruments, all of which are characterized by a pragmatic and unadorned style. He was the first person to make astrolabes by printing the component parts onto paper, which could then be glued to wood.

Scholars had previously made manuscript astrolabes, which they often affixed in their manuals. These instruments usually had only one side and were designed for specific purposes, such as casting horoscopes. Hartmann's paper astrolabes, by contrast, were complete instruments. Because they were inexpensive, they found a ready market.

In the 1530s, the center of production moved west into the Low Countries. The ready supplies of copper and brass provided the material needed for the Antwerp-Louvain region to develop into the most important center for the manufacture of astrolabes and related instruments. As in the cases of Fusoris

in Paris and Hartmann in Nuremberg, the workshop in Louvain developed around a scholar-craftsman. Gemma Frisius (1508-1555 CE) had been educated at the University of Louvain, where he remained as a professor of medicine. Frisius set up a workshop and began making celestial and terrestrial globes. In 1552 Frisius's nephew Gualterus Arsenius (fl. 1554-1579) started working as the engraver in the workshop. Under Arsenius's direction, the workshop became the most important one in Europe, making dozens of astrolabes for patrons in Spain, France and England. Arsenius's instruments are characterized by their fine craftsmanship and beautiful engraving. Astrolabes produced in Arsenius's workshop established a style for astrolabes and were widely copied. Thomas Gemini (ca. 1524-1591 CE), who produced instruments in London, made astrolabes in the Louvain tradition. Erasmus Habermel made Arsenius-style astrolabe while living and working at the Holy Roman Court in Prague.

SECTION 4

Craftsmen and Workshops

IMPORTANT CRAFTSMEN

- Ḍiyā' al-Dīn Muḥammad was the most prolific of an important family of astrolabe makers in 17th-century Lahore.
- Jean Fusoris produced practical yet elegant astrolabes in his workshop in 15th-century Paris.
- Georg Hartmann printed paper templates that were cut out and pasted onto wood.
- In Louvain Gualterus Arsenius set up the most important workshop in late 16th-century.
- Thomas Gemini produced ornate astrolabes for Queen Elizabeth I.
- Muḥammad ibn Aḥmad al-Baṭṭuṭī was still making astrolabes in 18th-century Morocco.

There is no single method for making and decorating an astrolabe. In fact, there are nearly as many approaches manufacturing astrolabes as there are manufacturers. Some craftsmen, especially Islamic makers, often employed artists to decorate instruments. In some cases, both the craftsman and the artist signed their astrolabes. Most astrolabes do not, however, bear any signature.

A maker's signature identifies not only who made that particular astrolabe but also provides evidence about where and when the astrolabe was produced. Such inscriptions can suggest the relationship between the maker and his instrument as well as the place of the astrolabe in contemporary culture. Astrolabes that bear both a maker's and a decorator's signature offer a glimpse at the hierarchies that structured workshops and the relationships between makers and decorators.

In some cases, the craftsman or decorator also included the name of the owner, typically the person who commissioned the astrolabe. Although there is no definitive way craftsmen or decorators signed their instruments, some patterns do emerge. Islamic makers and decorators more commonly signed their astrolabes than did later, Latin craftsmen.

At one end of the spectrum are the terse, direct inscriptions. For example, the 16th-century craftsman Erasmus Habermel signed his astrolabes: "Erasmus Habermel fe:", that is "Erasmus Habermel made [this]." Thomas Gemini, who made astrolabes for Queen Elizabeth I, was even more succinct. At the bottom of one of his astrolabe is simply: "Thomas Ⅱ 1559."

While retaining some authorship, these short signatures deemphasized the maker and emphasized the person for whom the astrolabe had been made or who late owned the instrument.

Islamic makers were generally more elaborate in their inscriptions. Even when short, Islamic inscriptions offered more information. For example, the maker Muḥammad Tāhir and the artist ʿAbd al-A'immah both signed the astrolabe they produced. In a delicate cartouche on the back of the instrument we read: "Made by Muḥammad Tāhir. Embellished by ʿAbd al-A'immah." They probably worked together in a workshop of some sort, for much the same signature is found on another instrument. Islamic makers were sometimes humble. For example, Qa'im muḥammad signed his instruments "Qa'im muḥammad the least servant." At other times these craftsmen were boastful, identifying their works as "Among the objects skilfully made by Muḥammad ibn Saʿīd as-Ṣabbān."

Signatures on Islamic instruments also explicitly link their astrolabes to particular political and religious authorities. A large, ornate astrolabe at the Museum of the History of Science, Oxford, was made as a gift for the Shāh ʿAbbās:

"I engrave this in the time of the just sultan, the greatest, the glorified Khāqān, master of the sovereigns of the Turks, the Arabs, the Persians, legitimately the sultan of the sultans of the horizons, and master of the necks of the nations, Shāh ʿAbbās, the Safawid, the Husainite, Bahādur Khān. May God make eternal his sovereignty and his power, in the year 996."

While this inscription might be more elaborate than most, it underscores its function as a symbol of political authority. Inscriptions on other astrolabes indicate that they were given as gifts to and intended to glorify mosques.

By far the most important workshop in medieval Europe was established by Jean Fusoris in 14th-/15th-century Paris. Fusoris's instruments are marked by a practical, elegant aesthetic and challenge easy divisions between scholar—craftsman—merchant. Along with his instruments, Fusoris composed his own treatise on the astrolabe in which he discussed various innovations that he introduced into his workshop.

We know of more makers in the 16th century. In the early part of the century, Georg Hartmann set up shop in Nuremberg. Like Fusoris, he adopted a practical aesthetic for his brass astrolabes. Among his innovations was printing the parts of astrolabes on paper. The parts were then cut out and pasted onto some sort of support, most commonly wood. This made astrolabes much more affordable. Perhaps responding to increasing demand for instruments, Hartmann exploited the advantages that print offered to reach a broader market. Unfortunately, his use of paper also made these astrolabes less durable. Consequently, his wood-and-paper astrolabes do not survive in great numbers.

Later in the century, Gualterus Arsenius's workshop in Louvain established in a new, considerably more ornate astrolabes. Arsenius's astrolabes were as much works of art and symbols of authority as they were practical instruments. They

were clearly intended for an elite audience. Many of the more prolific makers in the late 16th century tried to emulate Arsenius's instruments, either because they had trained in Louvain or because they recognized Arsenius's instruments as the standard. Both Erasmus Habermel and Thomas Gemini produced astrolabes that resembled Arsenius's for emperors, monarchs, and princes across Europe. By the end of the 16th century Ptolemy's humble flattened globe had become a symbol of status and power.

Although the production of astrolabes dropped off rapidly in the early 17th century, in the Islamic world craftsmen continued producing them for another couple hundred years. In Morocco, for example, we know that a Muḥammad ibn Aḥmad al-Baṭṭuṭī was still making astrolabes well into 18th-century.

SECTION 5

Uses

KEY USES

- Telling time—astrolabes often provided two different schemes for telling time, equal hours and unequal or seasonal hours
- Religious observation—Islamic astrolabes offered a number of religious functions, from determining prayer times to determining the direction of Mecca.
- Astrology—some of most common uses for an astrolabe were astrological, lines and scales facilitated drawing horoscopes, determining lunar mansions, and planetary rulers.
- Surveying—in principle the astrolabe could be used to perform a number of surveying type operations, from determining heights and depths to distances.

The astrolabe is an extremely versatile instrument, offering solutions to problems as diverse as telling the time, constructing horoscopes, determining direction and measuring the heights of buildings. The earliest texts on the use of the astrolabe, such as the Greek texts by John Philoponus and Theon of Alexandria or the Syrian text by Sebokht, concentrate on the astrolabe's celestial uses. By the time al-Biruni wrote his treatise on using the astrolabe, in the early eleventh century, it was expected that such texts would catalog both celestial and terrestrial functions. He detailed how to tell the time during the day or night, determine the astrological ascendent, rectify the horoscopic houses as well as how to determine the width of a river, the depth of a well and the height of a minaret.

Later authors expanded this taxonomy of uses, indicating how to calculate the course of a disease, how to measure the proportions of a building, how to construct topographic maps, and how to determine the movements of a distant enemy. Throughout the medieval and early modern periods scholars produced innumerable thick tomes as well as handy reference manuals that detailed the astrolabe's multifarious uses. The demand for these 'how-to' manuals was so great that they were often translated into various languages and reprinted in different formats.

Throughout its long history, texts on the astrolabe consistently addressed four types of operation: telling time, religious observation, astrological calculations and surveying. The following is not meant to be a how-to manual but rather an introduction to some of the ways astrolabes could be used.

Time

Telling time is perhaps the most common use for an astrolabe. Many astrolabes contain two different systems for telling time. The first and most common system is the equal hours. This system divided the day into 24 equal hours. The equal-hour scale was found around the rim of the instrument, typically numbered from 1 to 12 twice.

The first six equal hours.

A second system was introduced later. This system is referred to as either the unequal or seasonal hours. In contrast to the equal hours, the unequal hours divide the daylight or the darkness into 12 equal parts. Consequently, in the summer the day-time hours are longer than the night-time hours. In the winter, just the opposite is true. Only at the spring and fall equinox were the day-time and night-time hours the same length. For this reason the system was sometimes called the seasonal hours. The lines that denoted the unequal hours were typically engraved on the plates. On Islamic astrolabes, especially those made in North Africa and Muslim Spain, often another set of five lines was engraved on the various plates. These lines indicated the five daily prayer times.

Curved lines denote the seasonal hours.

Religion

In subtle but important ways, the astrolabe often functioned within a religious context. Islamic makers commonly inscribed the thrones of their instruments with a quotation from the Qur'an, usually Surah 2, verse 256 or Surah 6, verse 59. The religious connection was not merely symbolic. Astrolabes could be used in religious practice.

Religious observation has always been closely linked to the motions of the heavens. Many important Christian dates are determined astronomically: Easter is only the most obvious. Islam continues to rely on a lunar calendar to determine its important religious celebrations, including Ramadan. Both Islam and Christianity prescribed times for daily prayers. The astrolabe's utility in determining the time made it ideally suited to these tasks. It is not surprising, then, to find that the astrolabe was often a useful tool for religious observations, ranging from finding the times to pray and the direction to Mecca, to calculating the date of easter and keeping a list of the religious feasts. Craftsmen also used the calendar on the backs of the astrolabe to record both common saint's days as well as important local saints. These traces help recover the religious and local context in which the astrolabe was used.

Astrology

Astrology constituted one of the primary uses of an astrolabe. On the one hand, astrolabes were useful for constructing horoscopes. Drawn for a particular moment, the horoscope is a schematic representation of the heavens for that instant as seen from a particular place. The astrologer began by placing the signs of the zodiac on the horoscope. This was called dividing the houses. There were various methods of dividing the house, but the astrologer typically began by finding the four cardinal points: the ascendent, the point of the zodiac rising above the eastern horizon; the descendent setting on the western horizon; the point directly overhead; and the point diametrically opposite that one. The astrologer then determined the divisions for the houses below the horizon and finally calculated the divisions for the remaining houses above the horizon. In this figure the astrologer then plotted the seven known planets and any bright stars he considered important to the horoscope.

Some astrolabes were made specifically for dividing the houses. Commonly, craftsmen engraved special lines on the plates to make it easy to find the house divisions or other astrologically important information. Even astrolabes that did not include such lines were easily used to construct horoscopes. In these cases, the astrologer relied on the unequal hour lines engraved on the plates of most later astrolabes.

On the other hand, astrolabes also served as handy astrological reference tools. Persian astrolabes are richly decorated with astrological tables covering the lower half of the back of the instrument. European craftsmen displayed less regularity in both the types of astrological tables they included on their astrolabes. Nonetheless, they did not hesitate to engrave a vast range of astrological tables and scales onto the backs and into the wombs of their instruments. All of these tables presented different astrological systems for understanding heavenly influences on earth. In other words, the astrolabe was well suited to the needs of astrologers and all evidence suggests that it was widely used for such purposes.

Surveying

In addition to its applicability to celestial questions, the astrolabe was equally suited to solving terrestrial problems thanks to its combination of observational and calculation scales, especially the shadow square found on most astrolabes. Al-Biruni listed just a handful of surveying operations. Messahalla elaborated on this list, and by the sixteenth century, surveying uses had become an obligatory section of any astrolabe manual. The most common surveying uses were determining the height of towers, the depths of wells, and distances. Authors often included a vast range of variations on these themes: various ways to find the height of towers you could reach and those you could not reach; the height of a parapet above the top of a wall; the thickness of some fortification; the width of a well.

SECTION 6

Collecting Astrolabes

IMPORTANT COLLECTIONS

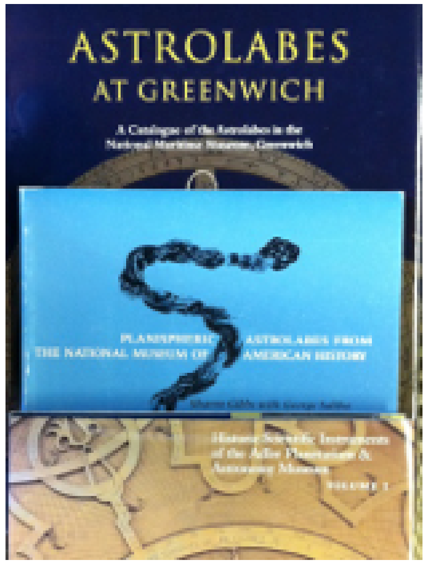
- In the late 19th century Lewis Evans amassed a large collection of astrolabes, which he donated to the University of Oxford.
- Evans's collection forms the core of the largest collection at The Museum of the History of Science in Oxford.
- The generous patronage of James Caird enabled the National Maritime Museum in Greenwich to develop the second largest collection.
- Science museums like the Adler Planetarium in Chicago and the Museo Galileo in Florence also have large collections.

In Europe, interest in astrolabes as mathematical instruments declined in the seventeenth century. Although some makers still produced astrolabes, by the early eighteenth century production had nearly stopped. During this same period, scholars increasingly collected astrolabes as antiquities rather than as instruments to be used. Both the antiquarian John Selden (1584-1654) and William Laud (1573-1645), the Archbishop of Canterbury, collected astrolabes as objects rather than instruments. The interest in astrolabes as objects had its most thorough expression and revision in the efforts of Lewis Evans in the late nineteenth and early twentieth centuries. Unlike earlier antiquarians, Evans collected astrolabes because of their importance as objects of historical significance. Consequently, he believed that they should be made available to the public and in 1924 presented his collection to the University of Oxford. Six years later Evans's collection of astrolabes and related instruments and books were made available to the public in the newly opened Museum of the History of Science. Today, the astrolabes in the Lewis Evans Collection of Historic Scientific Instruments, many of which are on display, form the core of the museum's collection of astrolabes and help make it the largest in the world.

The second largest collection of astrolabes is at the National Maritime Museum in Greenwich. The museum was established by an Act of Parliament in 1934, at a time when a number of museums were established for collections that did not fit the standard art or antiquities model. A number of science museums can trace their founding to the late 1920s and early

1930s—The Museum of the History of Science in Oxford, the Museo Galileo in Florence (then the Instituto e Museo di Storia della Scienza), and in Chicago both the Adler Planetarium and the Museum of Science and Industry. Like these other museums, the National Maritime Museum was devoted to the preservation of scientific artifacts. Unlike its peer institutions, however, the collection of astrolabes at the National Maritime Museum were not acquired in large donations but through the persistence and perseverance of an early benefactor, Sir James Caird. Thanks to Caird's generous support, during the 1930s the museum acquired hundreds of instruments and dozens of astrolabes.

Other collections began and remained largely as personal adventures. The astrolabes that formed the core of the Time Museum in Rockford Illinois was one such collection. In the 1960s Seth Atwood decided to begin purchasing "pieces so that we could have a historical record" of timekeeping devices. He wanted to understand how these instruments "are the products of peoples, nations, cultures, and of economic and political systems." In the end, Atwood acquired at least a couple dozen astrolabes, which figured prominently in his collection of horological instruments. For three decades Atwood's collection introduced visitors to the technical developments in the history of horology. Unfortunately, the Time Museum closed in 1999 and after a short stay at Chicago's Museum of Science and Industry, the individual pieces were sold.

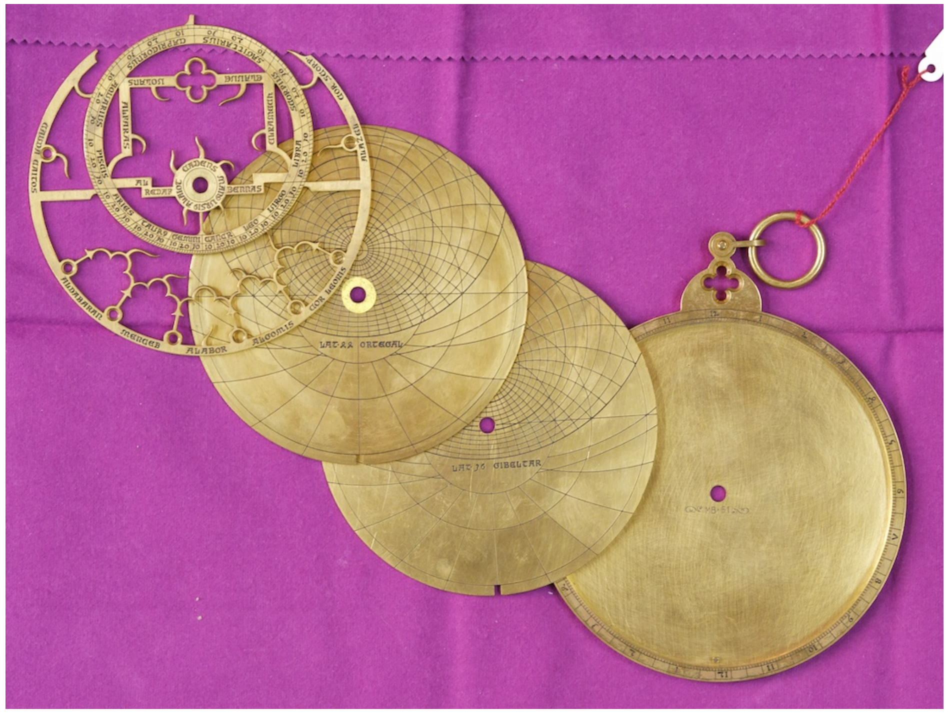


Astrolabes are no longer confined to science and history of science museums. While such museums possess the largest collections, art museums often possess at least a few and frequently borrow astrolabes for special exhibitions. Over the course of the 20th century astrolabes became increasingly expensive as the market for them expanded and particularly as wealthy collectors sought to add them to their private art collections.

Some of the larger collections of astrolabes are at the Museo Galileo in Florence, the National Maritime Museum in Greenwich, the British Museum in London, the Adler Planetarium in Chicago, and the Smithsonian Museum in Washington DC.

CHAPTER 2

The Parts



Little Lewis, my son, I see some evidence that you have the ability to learn science, number and proportions, and I recognize your special desire to learn about the astrolabe. So, as the philosopher said, “he serves his friend who grants his friend’s wishes”, I propose to teach you some facts about the instrument with this treatise.

Chaucer, *A Treatise On the Astrolabe*.

The most common type of astrolabe is the planispheric astrolabe, often simply called the “astrolabe”. The astrolabe is a portable instrument, usually made of brass, and measuring between 4” and 12”, though some are much larger or much smaller. It is designed to measure the altitude of the sun, moon or stars and to determine various astronomical and topographical relations. A complete astrolabe will have a number of individual parts.

The front of an assembled astrolabe.

At the top of the instrument is a ring, which is connected to a shackle, usually a U-shaped piece of metal. The shackle, in turn, is affixed to the throne, usually by means of a pin that allows the shackle to pivot. Together, these three pieces are used to hang the instrument so that it can be used to make observations.

The ring, shackle, and throne.

On Thrones: The throne on an astrolabe reflected the aesthetic choices of its maker. On European instruments, such as the one above, the throne was often small and relatively simple. On astrolabes from Iberian and North Africa, the throne was often broad and did not extend up much from the edge of the instrument. Thrones on astrolabes from the eastern portion of the Islamic world were ornate, tall, and often had an inscription from the Qur’an on the front or the back.

The body of an astrolabe is called the mater. The front of the mater has a raised outer rim called a limb. The limb is fre-

quently marked with one or two scales that can be used for telling time. The hollowed out depression in the front of the instrument is the womb. On most western astrolabes, the womb

The front of the astrolabe is hollowed out. Various plates and the rete are then placed in this womb.

is left blank. By contrast, astrolabes from the eastern half of the Islamic world often contained a gazetteer, a type of atlas that provided relevant geographic information for important cities in the Islamic world.

Altitude, zodiacal, and calendar scales on the back of an astrolabe.

The back of the astrolabe is usually flat and is engraved with various scales and tables. The most common set of scales were altitude scales, a zodiac, a calendar, and a shadow square. The outermost scale was the altitude scale around the rim of the instrument. This scale was used to determine the inclination of the sun, a planet, or a star. Moving toward the center of the instrument, next scale is the zodiac. Western astrolabes typically included a Julian, i.e., the Christian, calendar just inside the zodiac. This offered a convenient way to determine the place of the sun in the zodiac for any given day of the year. By contrast, in the eastern Islamic world where the Julian calendar played little role astrolabes rarely included a Julian calendar. The last, common set of scales is the shadow square in the lower half of the center. This set of scales was used for determining heights and distances of objects. Typically a range of astrological

scales were engraved on the backs of astrolabes.

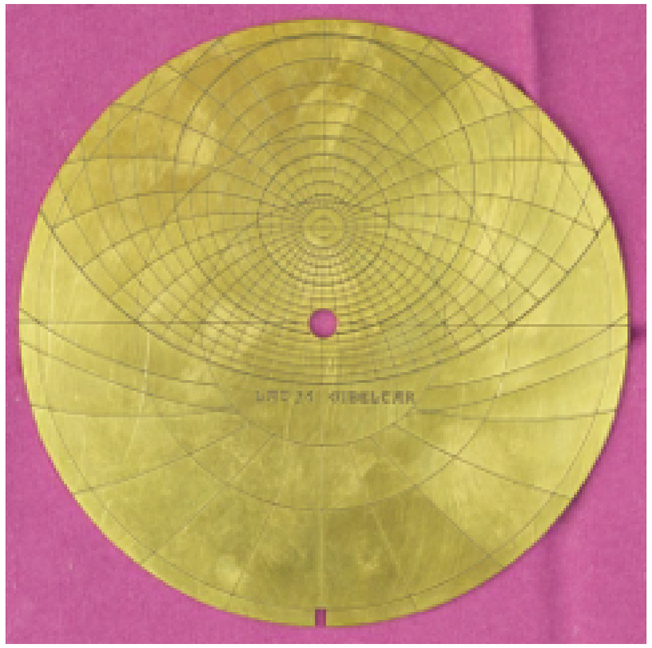
On Calendars: Calendar scales on the backs of astrolabes reveal the importance of cultural context in making instruments. Makers of astrolabes in Spain and North Africa often included the Julian calendar because they could expect their market to be familiar with and perhaps to use the Julian system. Yet when they did include the Christian calendar, they often transliterated the names of the months into Arabic letters.

Julian months transliterated into Arabic letters.

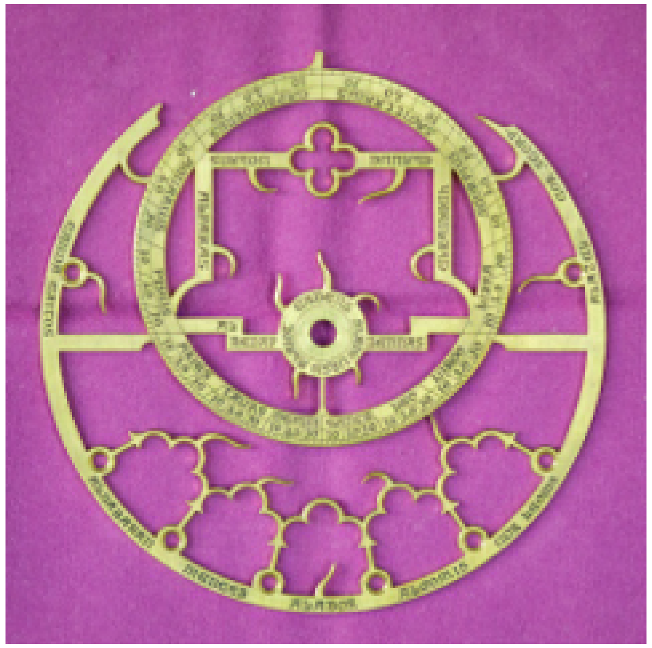
January	ينير;
February	فبرير
March	مارس
April	ابريل
May	مايه
June	يونيه
July	يوليه
August	اغشت
September	شتنبر
October	اكتوبر
November	نونبر
December	دجنبر

Because the year does not divide into an even number of weeks, the first day of the year drifts through the week. Latin astrolabes sometimes had perpetual calendars that could be used to determine which day of the week would be the first day of the year.

A few astrolabes from the eastern Islamic world include the Syrian Solar calendar. Similar to the Julian calendar, the Syrian calendar includes twelve months of alternating length and one short month of 28 or 29 days. The first day of the Syrian year corresponds to the first day of October in the Julian calendar.


A plate, engraved for 36° latitude and marked for the city of Gibraltar.

A number of thin plates are fitted into the womb. Each side of the plate is engraved with a stereographic projection of the heavens for a different latitude or city. The city and latitude were often engraved on the plate. The dense network of lines on the upper portion of the plate represents the visible sky at that location. The curved lines in the lower portion were used for telling time. European instruments often included thee plates for a total of six different latitudes. Islamic astrolabes, especially those from the eastern half of the Islamic world, not infrequently included six or seven plates. A small tab prevents the plates from rotating in the womb and ensures that they are aligned correctly. On European instruments, the tab extends from the plate into a notch in the limb. Most Islamic instruments, by contrast, have



Seventeen curved pointers on the rete indicate important bright stars.

a small tab extending from the limb that fits into a notch on the plate.

The rete rotates on top of the plates. It carries a stereographic projection of a selection of fixed stars as well as the ecliptic, the sun's yearly path. On early astrolabes there are typically only dozen or so stars. Some later, ornate instruments will have more than 40 stars on the rete. The rete can be set to show the positions of the fixed stars and zodiacal signs. European astrolabes often have a rule or pointer on top of the rete that makes it easier to read the scales on the front of the instrument.

An alidade is attached to the back of the instrument. It has two sighting vanes, each with at least one hole. The alidade is used to make various observations such as determining the height (i.e., the altitude) of the sun, moon or stars, or the height of a tower.

The instrument is held together by a pin that passes through a hole in the center of the instrument and extends out the front. The moveable parts, e.g., the rete, the alidade and rule, rotate

The back of the astrolabe contains various scales. Typically, these included altitude, calendar, and zodiacal scales, as well as the shadow square.

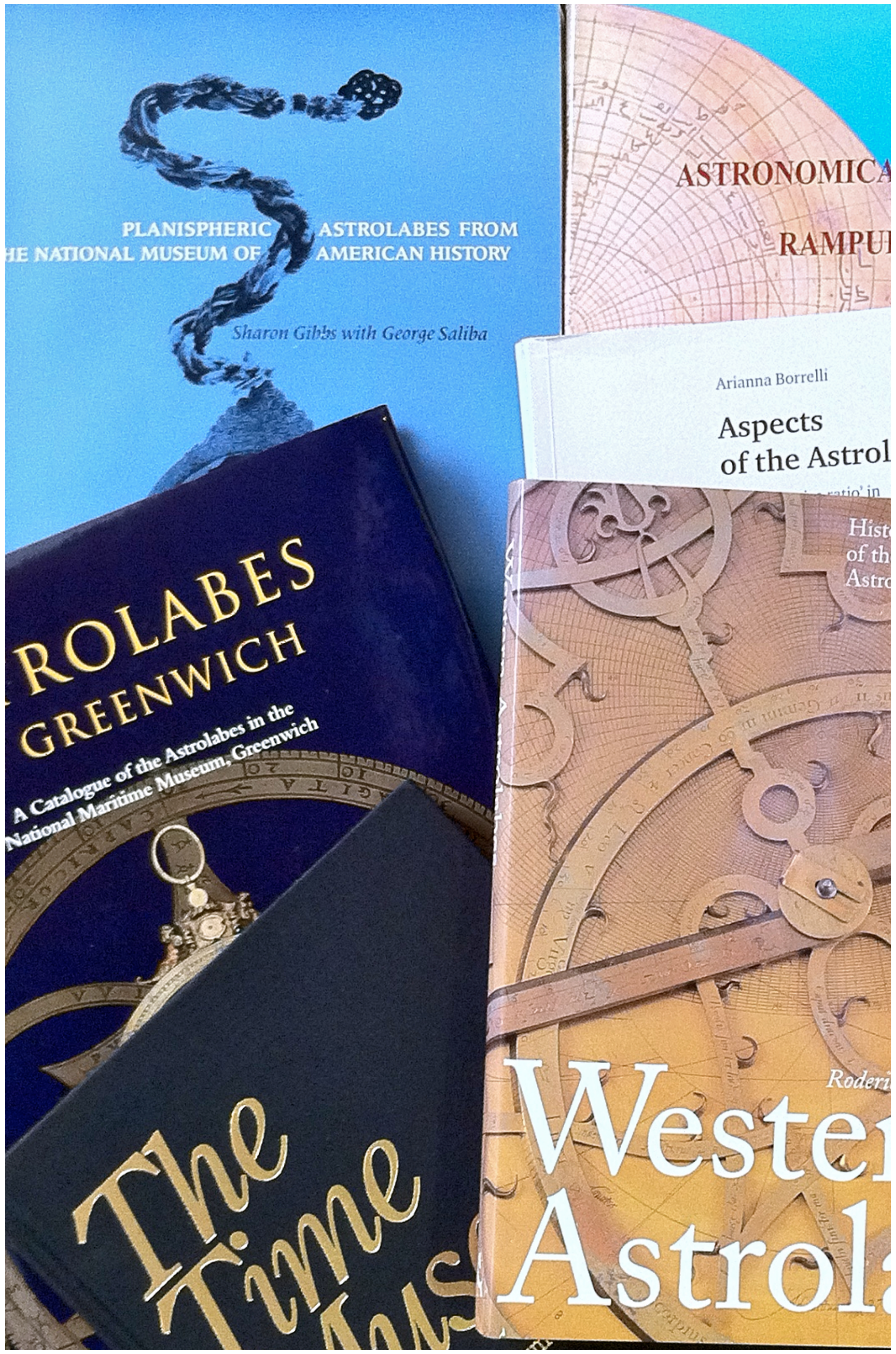
around the central pin. A wedge-shaped horse fits through a slot in the pin and secures the assembly.

The front of an assembled astrolabe. On top of the rete is a rule. The plate is visible through the rete.

The back of an assembled astrolabe, showing the alidade used for determining the elevation of the sun or star.

CHAPTER 3

Further Reading



The astrolabe is an instrument of the Greeks; its name Asturlabun, i.e., mirror of the stars, Hamzeh of Isfahan derived from the Persian as if it were sitara-yab (star finder). By its aid it is possible easily and accurately to know the time and how much of the day or night has passed, as well as other things too many to enumerate.
Al-Biruni, “The Astrolabe.”

The literature on astrolabes is immense. Items listed here represent some of that literature. The goal was to balance utility and scholarship with accessibility.

Articles:

A useful article for understanding how astrolabes work is J. D. North, "The Astrolabe" *Scientific American* 230 (1974): 96–106. The diagrams from North's article turn up everywhere. Another good introductory article is Willy Hartner, "The Principle and Use of the Astrolabe." In 1, *Oriens-Occidens* (Hildesheim: Georg Olms, 1968), 287–311.

On the construction of astrolabes, see Emmanuel Poulle, "La fabrication des astrolabes au Moyen Age" *Techniques et Civilizations* 4, no. 4 (1955): 117–28; Henri Michel "Méthodes de tracé et d'exécution des astrolabes persans" *Ciel et terre* 12 (1941): 481–96; Henri Michel, "Eléments du tracé d'un astrolabe" *Journal suisse d'horologerie* (1947): 483–89.

Otto Neugebauer's survey of the early history of the astrolabe is worth reading: Otto Neugebauer, "The Early History of the Astrolabe" *Isis* 40 (1949): 240–56. One of the only articles to think about the astrolabe in a context beyond timekeeping is David Proctor, "Astrology and the Astrolabe in Europe" *Maritime Monographs and Reports* 36 (1978): 109–24. This essay has finally been superseded by essays in Cleempoel's *Astrolabes at Greenwich* (see below). Owen Gingerich offers a nice study of an eastern astrolabe as well as some pointers about fakes and forgeries: Owen Gingerich, "An Astrolabe from Lahore" *Sky and Telescope* 63, no. 4 (April 1982): 358–60 and Owen Gingerich, "Fake Astrolabes" *Sky and Telescope* 63, no. 5 (May 1982): 465–68. Perhaps reflecting the rarity of the instruments, there are few articles treating Byzantine astrolabes. Nearly a century ago O.M. Dalton described the on surviving astrolabe: O.M. Dalton "The Byzantine Astrolabe at Brescia" *Proceedings of the British Academy* 12(1926), 133-146. Byzantine texts on astrolabes are much more common. An excellent survey is Anne Tihon, "Traités byzantins sur l'astrolabe" *Physis* 32 (1995): 323–57.

Catalogs:

Museum catalogs are wonderful resources because they often include introductory essays that give both a history of the astrolabe and an overview of the basic functions. They also offer beautiful photographs of the instruments. In no particular order: Sharon Gibbs and George Saliba, *Planispheric Astrolabes from the National Museum of American History* (Smithsonian: Washington, 1984)—available online <http://www.sil.si.edu/SmithsonianContributions/HistoryTechnology/pdf_hi/SSHT-0045.pdf>; Anthony J. Turner, *The Time Museum*, Astrolabes (Vol. 1, Part 1) (Time Museum: Rockford IL, 1985); Roderick and Marjorie Webster, *Western Astrolabes* (Adler Planetarium: Chicago, 1998); David Pingree, *Eastern Astrolabes* (Adler Planetarium: Chicago, 2009); Koenraad van Cleempoel, *A Catalogue Raisonné of Scientific Instruments from the Louvain School, 1530 to 1600* (Turnhout: Brepols, 2002); Koenraad van Cleempoel, ed. *Astro-*

labes at Greenwich: A Catalogue of the Astrolabes in the National Maritime Museum (Oxford: Oxford University Press, 2006). This last text is beautiful and remarkable for the impressive range of interpretive essays in it. Regrettably, it is also expensive.

Books:

For those looking for more extensive treatment than that found in museum catalogs, there are a range of options. James E. Morrison's book is probably the definitive book available: James E. Morrison, *The Astrolabe* (Janus, 2007). A shorter but still complete text is Harold N. Saunders, *All the Astrolabes* (Senecio: Oxford, 1984). Much shorter but more than sufficient for learning the basics is *The Planispheric Astrolabe* (National Maritime Museum: Greenwich, 1982). Both a history and instructions on constructing an astrolabe are found in James Evans, *The History and Practice of Ancient Astronomy* (Oxford: Oxford University Press, 1998).

For Islamic astronomical instruments, David King's magisterial 2-volume study is the place to start: David King, *In Synchrony with the Heavens, Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization* (Leiden: Brill, 2005).

Primary Sources:

As the first text written in English on the astrolabe, Chaucer's text has been reprinted a number of times. It is well worth reading: Chaucer, *A Treatise on the Astrolabe*, ed. Sigmund Eisner (Norman, OK: University of Oklahoma Press, 2002). Recently some translations of sixteenth century texts have been published. Read alongside Chaucer's work, these later texts show how much expectations had changed and how sophisticated texts had become: *Stoeffler's Elucidatio - The Construction and Use of the Astrolabe*, trans. Alessandro Gunella and John Lamprey (2007) and *Hartmann's Practika*, trans. John Lamprey (2002).

On-line Resources:

Considerable information on astrolabes is available online. Many of these websites include working Java script or Flash astrolabes, so you can see how one works. Other sites focus on particular, often technical details. The sites listed here indicate some of the rich material available.

Many museums have put all or part of their collection online. The best of these resources is the recent project at The Museum of the History of Science in Oxford: <http://www.mhs.ox.ac.uk/astrolabe/>. The National Maritime Museum has put many of their instruments online: <http://collections.rmg.co.uk/collections.html> where you can search for astrolabes (or this URL should limit the results to just astrolabes: <http://collections.rmg.co.uk/collections.html#csearch;searchTerm=astrolabe;terms=term-10029738>). The Museo Galileo also has posted a number of their astrolabes: <http://brunelleschi.imss.fi.it/museum/esim.asp?c=500169>. The Museum of the History of Science maintains a combined

database of instruments, EPACT, that brings together instruments from a few different museums: <http://www.mhs.ox.ac.uk/epact/>.

Various sites have developed working versions or offer videos showing how to use an astrolabe. Keith's Astrolabe provides a Java applet version <http://www.autodidacts.f2s.com/astro/index.html>. Lyte Lowys and the Pol Hors has a Flash version: <http://emademe.com/astrolabe/PolHors.html>. James Morrison maintains one of the best sites on all aspects of the astrolabe. There you can download a DOS program that emulates an astrolabe: <http://www.astrolabes.org/pages/electric.htm>. The Museum of the History of Science offers a short video showing how to tell time with an astrolabe: <http://www.mhs.ox.ac.uk/exhibits/using-anastrolabe/>.

For the mathematically inclined, various sites provide more or less detailed descriptions of the stereographic projection. See, for example: <http://www.math.ubc.ca/~cass/courses/m309-01a/montero/math309project.html>

Chaucer's text is available at numerous websites, both as HTML files and PDF files that you can download. Here is an HTML version: <http://www.chirurgeon.org/treatise.html>. And here is a PDF version: <http://www.chirurgeon.org/files/Chaucer.pdf>.